# Design of Miniaturized-Element Frequency Selective Surface Using Neural Networks

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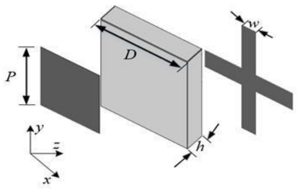
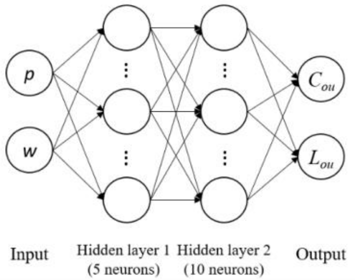
## Introduction

In this paper, firstly, the coupling phenomenon between MEFSS layers is analyzed in detail, and a new equivalent circuit model is proposed. Secondly, the BP neural network is used to fit the relationship between the coupling capacitance, coupling inductance and the structural parameters. The relationship of equivalent circuit component and structural parameters is established. Finally, the validity of the equivalent circuit model and the electrical value is verified and summarized.



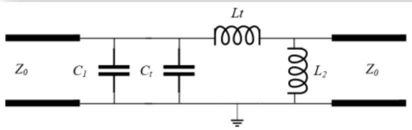



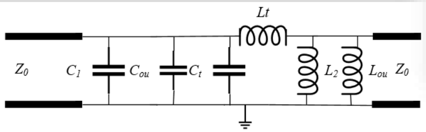

## Equivalent Circuit Model and Coupling

The first-order MEFSS unit structure is shown in Figure. It is composed of a single-layer metal patch and a single-layer metal wire grid cascaded through dielectric substrate with   and  . Patch length is P, wire grid width is w. The thickness of the dielectric substrate is 0.5 mm. Based on the four mapping formulas of the MEFSS unit, the equivalent circuit diagram without the coupling effect is firstly obtained, as shown in Figure.

Put this structure into the HFSS simulation software for full-wave simulation to obtain the frequency response result, and compare it with the uncoupled simulation result of the equivalent circuit model to fit and compare the amplitude of the transmission response, and obtain the required "coupling capacitance" Cou and "coupled inductance" Lou, as shown in Figure.

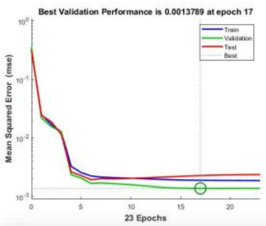
In the equivalent circuit model, the coupling effect of the first-order MEFSS unit is equivalent to a capacitor in parallel with the capacitance layer and an inductor in parallel with the inductance layer, that is, the actual capacitance value increases and the inductance value decreases in the circuit. In order to further explore the influence of structural parameters on the coupling effect, other variables are kept the same, and electrical values are obtained by changing the structural parameters of the unit metal layer, which are used for neural network training.

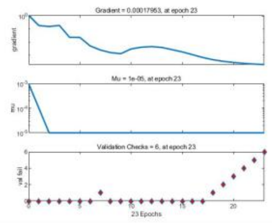


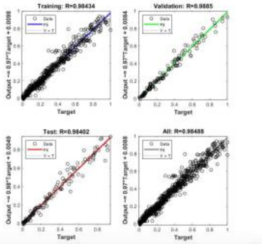




## Neural Network Design and Training

First, set the sweep parameters of the structure through the full-wave EM simulations to collect dataset. The generated database of structural parameters and electrical values contains 440 sets of data. Fit and compare the amplitude of reflection and transmission parameters in coupled equivalent circuit model, and obtain the required Cou and Lou which need normalization. After preprocessing, 80% of the dataset will be used as training set for neural network training. The remaining part is divided into two halves to form a validation set and a test set. The training process and results are shown in Figure. Figure shows the change in mean squared error of the entire neural network training. The best validation performance is 0.0013789 at epoch 17. Figure shows the changes of gradient and learning rate respectively. The gradient is in a downward trend in the training phase, and finally the training is completed in the epoch 23. Figure is regression plot, which shows the R values of the training set, validation set and test set respectively. The closer the R value is to 1, the better the fit. After validation, the final fitting degree of all samples can reach 98.85%.



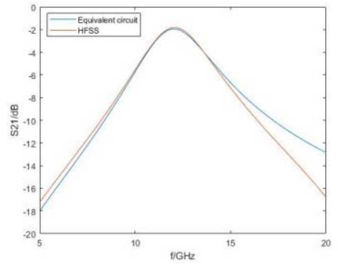



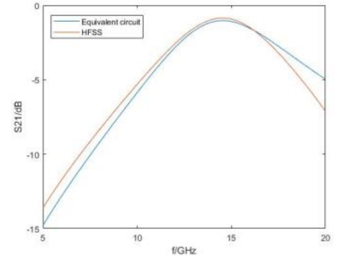

## Verification of Results

Figure, the results are verified by comparing the results of the full-wave simulation with those of the equivalent circuit for structures in Table.

It can be found that the corresponding center frequencies of the two structures are the same, and the transmission coefficients near the center frequencies are basically consistent.

| | p(mm) | w(mm) | D(mm) |
|---|---|---|---|
| I | 4 | 1 | 6 |
| II | 5 | 1.5 | 6 |




## Conclusion

In this paper, we propose an equivalent circuit construction method. By taking fully consideration of the coupling between layers in the MEFSS structure, the proposed equivalent circuit model can achieve better equivalent accuracy compared with traditional models. Additional, BP neural network helps to quickly calculate structural parameters and component values, replacing the process of full-wave simulation and optimization. Verification of second-order and third-order MEFSS proves that the correctness of cascade in final. The new equivalent circuit and extension bring direction to the solution of N-order MEFSS equivalent circuit.